MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Decarbonisation portfolio

Introductory slides

2021.10.25
Mitsubishi Power Europe GmbH

MITSUBISHI POWER

Company Overview

** This table is not exhaustive. It lists only companies and products related to hydrogen business*

Mitsubishi Power is the thermal power generation company within the MHI Group.

MITSUBISHI HEAVY INDUSTRIES GROUP

Research & Innovation Centre

Energy Systems	Plants and Infrastructure	Integrated Defense and Space Systems
		
Jet Engines (Mitsubishi Heavy Industries Aero Engines, Ltd.) Offshore Wind Turbines (MHI Vestas Offshore Wind A/S) Compressor (Mitsubishi Heavy Industries Compressor Corp.)	Iron Making (Primetals Technologies, Ltd.) Ammonia & Methanol Co-Production Plants CO2 Capture Plants (Mitsubishi Heavy Industries Engineering, Ltd.) Gas Carriers (Mitsubishi Shipbuilding Co., Ltd.)	Aircraft (Mitsubishi Aircraft Corporation) H-IIA Rocket

MHI Group Capabilities

The MHI Group has a vast range of technologies and end-to-end solutions for the hydrogen supply chain

Production → **Transportation** → **Demand**

Gasification Plants

CO_2 Capture Plants

Ammonia & Methanol Co-production Plants

Hydrogen Gas Turbines

Offshore Wind Turbines

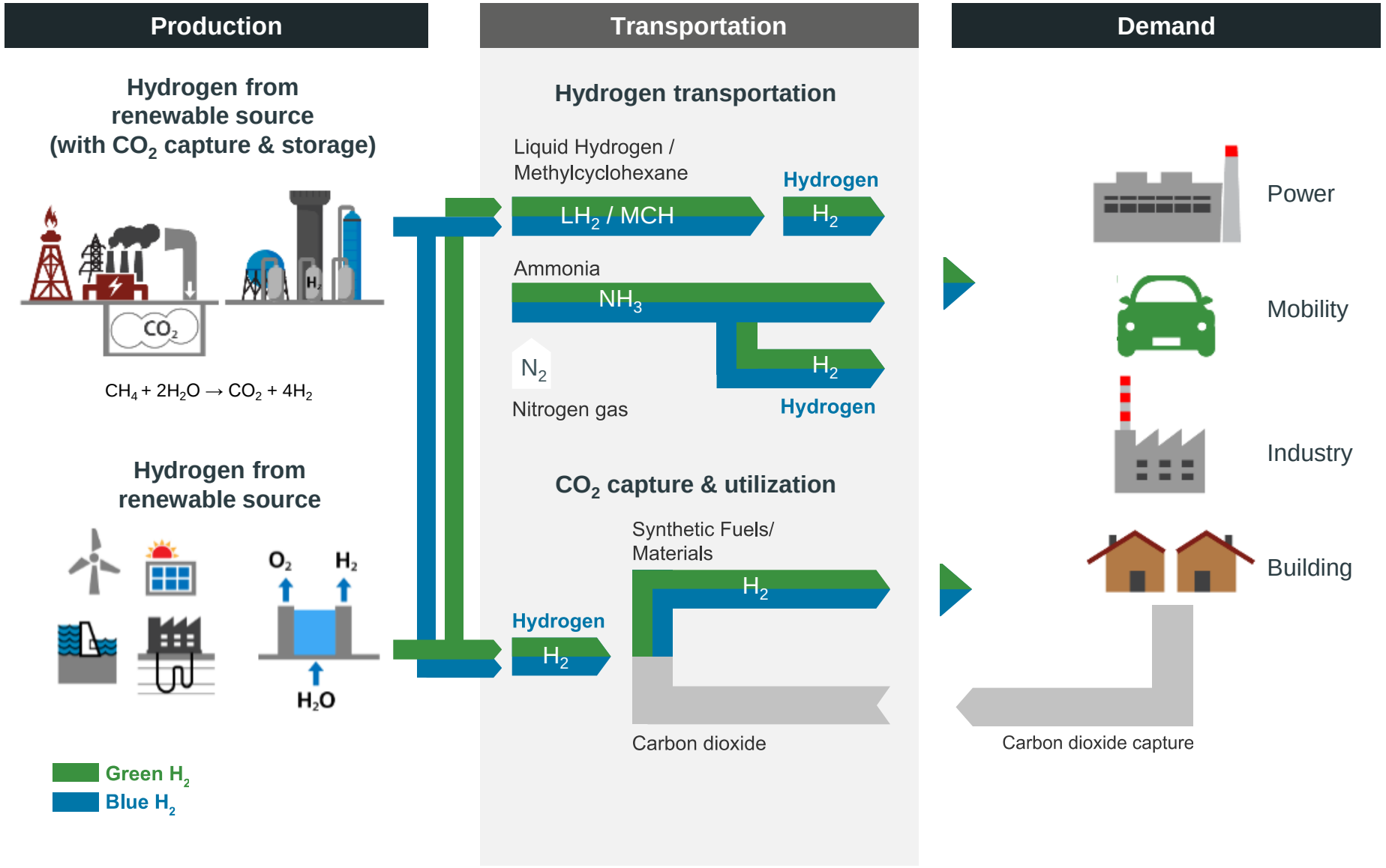
Compressors

Gas Carriers

Hybrid Fuel Cell Generators

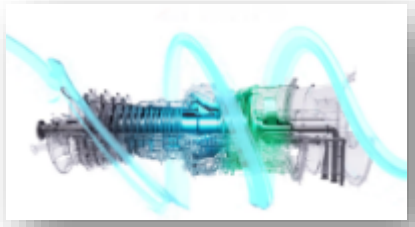
In addition, MHI Group has products for iron making, forklift, rocket, etc. that can be fueled by hydrogen.

Overview of Global Hydrogen Supply Chain



Hydrogen in Heat & Power Generation

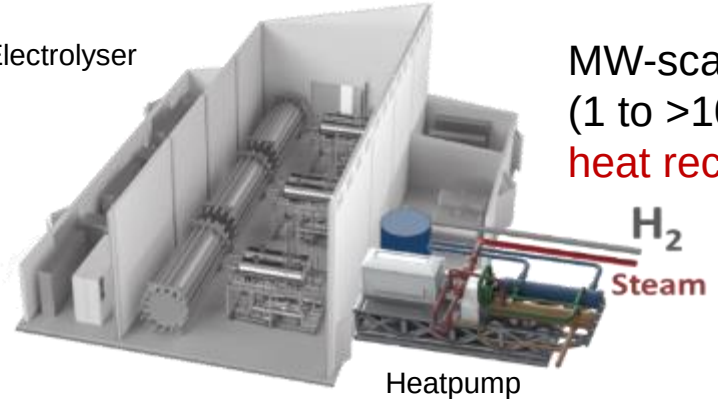
Solid Oxide Fuel Cell
"MEGAMIE"
(1 MW)



Gas turbine in combined cycle power plants:
up to GW scale

"hydrogen readiness" is a key requirement for near future in EU market

Hydrogen production & Sector Integration



MW-scale electrolyser
(1 to >100MW) + heat pump for waste heat recovery

Industrial Scale
Carbon Capture

"blue hydrogen" and CCU require large scale CO2 capture

Petra Nova Plant, US
4776 t/day CO2 capture

MITSUBISHI HEAVY INDUSTRIES

Electrolyser

MITSUBISHI HEAVY INDUSTRIES

PRESS INFORMATION

MHI Group Undertakes Investment in HydrogenPro of Norway, Leading Producer of Advanced Electrolyzers -- Move Will Contribute to Creation of a Sustainable Society through Hydrogen Energy --

2020-10-14

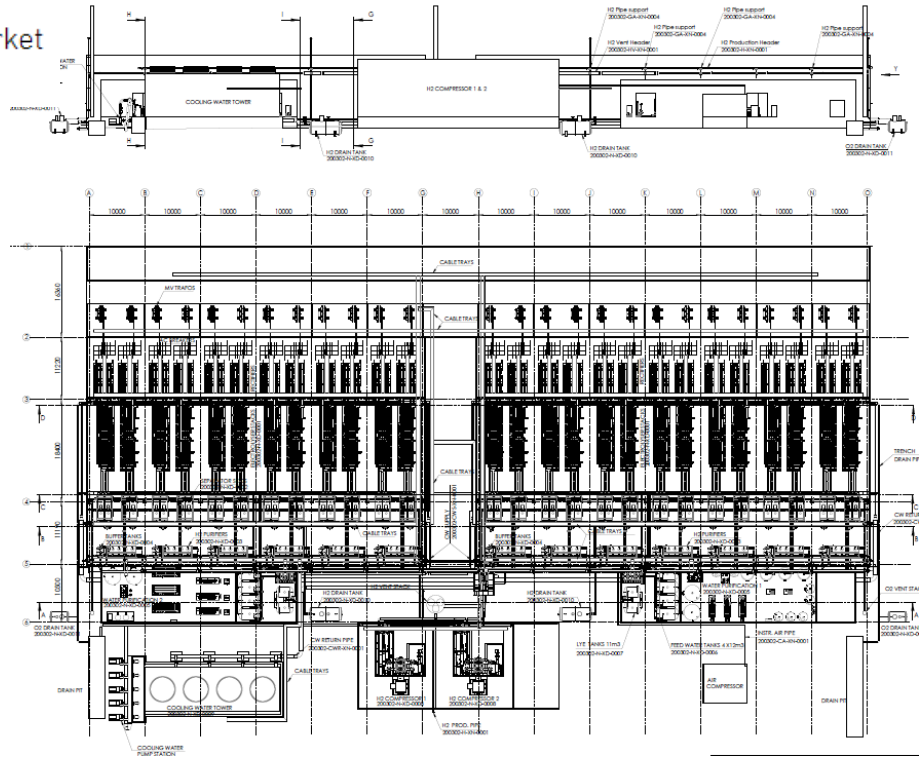
- Investment will make MHI an industrial partner supporting HydrogenPro's business expansion
- Strategic collaboration in hydrogen production will strengthen and diversify MHI's hydrogen value chain

Tokyo, October 14, 2020 - Mitsubishi Heavy Industries, Ltd. (MHI) has made a financial investment in HydrogenPro AS of Norway, a company engaged in the development and manufacture of electrolyzers, devices that produce hydrogen by the process of water electrolysis. MHI subscribed to newly issued shares placed by HydrogenPro in an initial public offering (IPO) undertaken to fund expansion of its business operations. MHI already provides various decarbonization technologies that allow for a realistic path towards net-zero and will form the strategic partnership with HydrogenPro to further expand its portfolio and provide green hydrogen production plants to the market going forward.

https://www.mhi.com/news/201014.html

HydrogenPro was established in 2013 based in the Norwegian city of Porsgrunn, Telemark County. The history of water electrolysis technology traces back to 1927, when a fertilizer and heavy water plant employing water electrolysis technology was launched in Telemark by Norsk Hydro, a Norwegian state owned conglomerate. HydrogenPro has already developed a 9 megawatt (MW) class hydrogen production system (production capacity: 4.4 tons/day) adopting water electrolysis technology incorporating a pressurized cells with alkaline electrolyte. Plans are now underway toward achieving a 100 MW class plant (capacity: 48 tons/day).

MHI's investment in HydrogenPro provides further financial stability and long-term certainty for projects utilizing green hydrogen to decarbonize various sectors. MHI's investment in HydrogenPro not only signals its confidence in HydrogenPro's offerings, but more importantly, this investment underscores its confidence in the green hydrogen market which will be supported by a multitude of electrolyzer manufacturers and technologies.



Hydrogen pro

Work in progress,
Preliminary arrangement
100MW(el) class

H2 electrolyser

Type	Op.- Pressure (bar)	Spec. Power (kWh/Nm³)	Turnkey (€/kW)
Pressurized Alkaline Electrolyzer	15-30	< 4,5 (AC)*	~1000 €/kW*

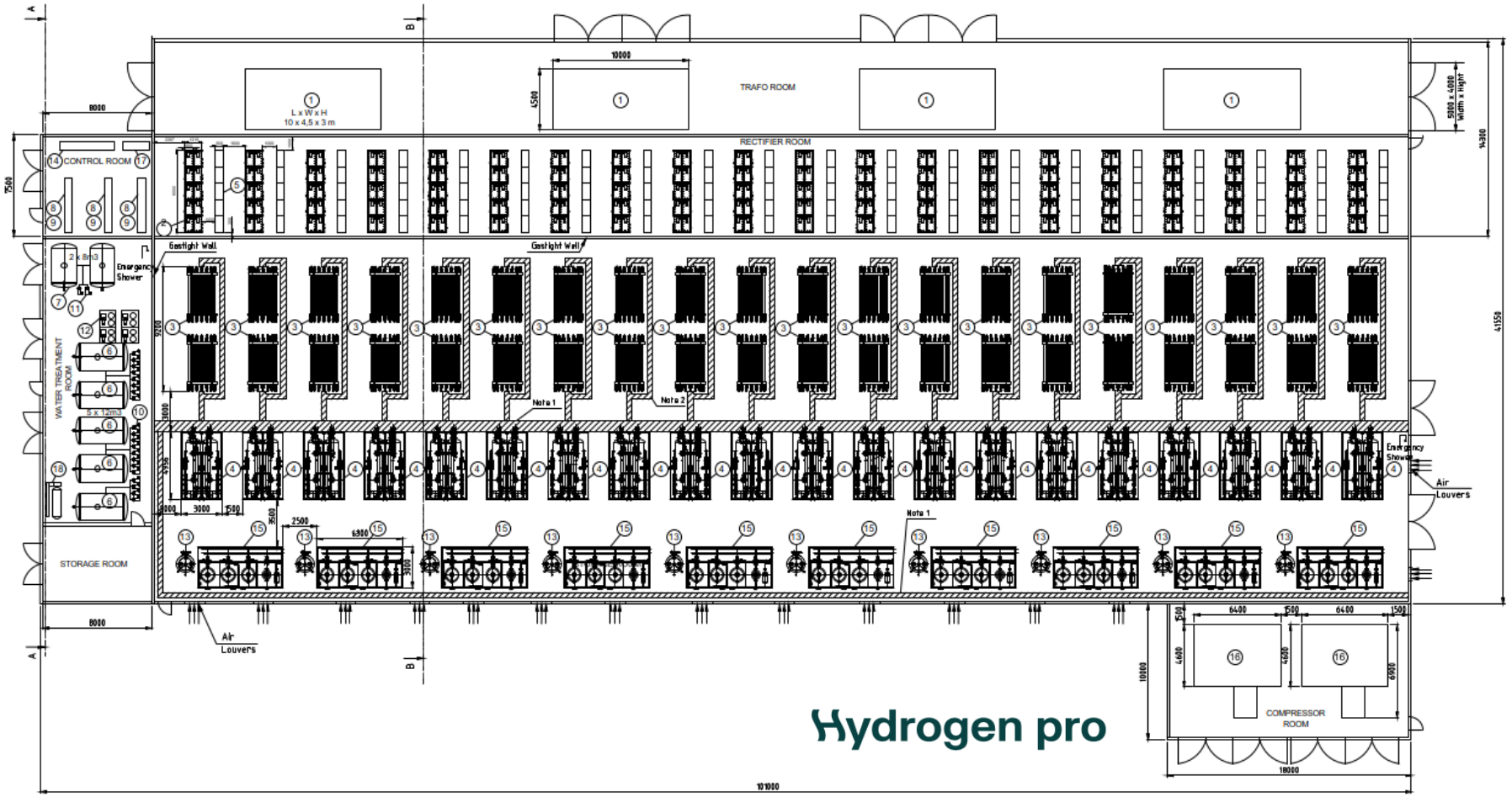
Hydrogen pro

* 100MW scale, basload operation proposed solution, for < 4000 full load hours cost optimisation can be done with the same technology by higher current density, lower efficiency (with today‘s electrodes) but up to 30% reduced cost

100 MWel scale with traditional technology

Typical large scale hydrogen production process 2018

100MW plant



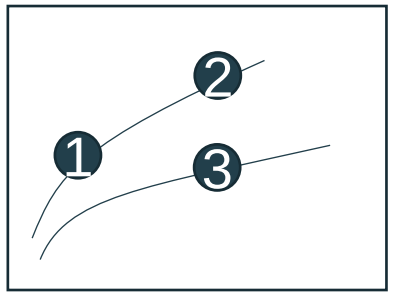
51 kWh in total to produce 1 kg H2 (already pressurized to 15 bars)

Future plant design large scale production process

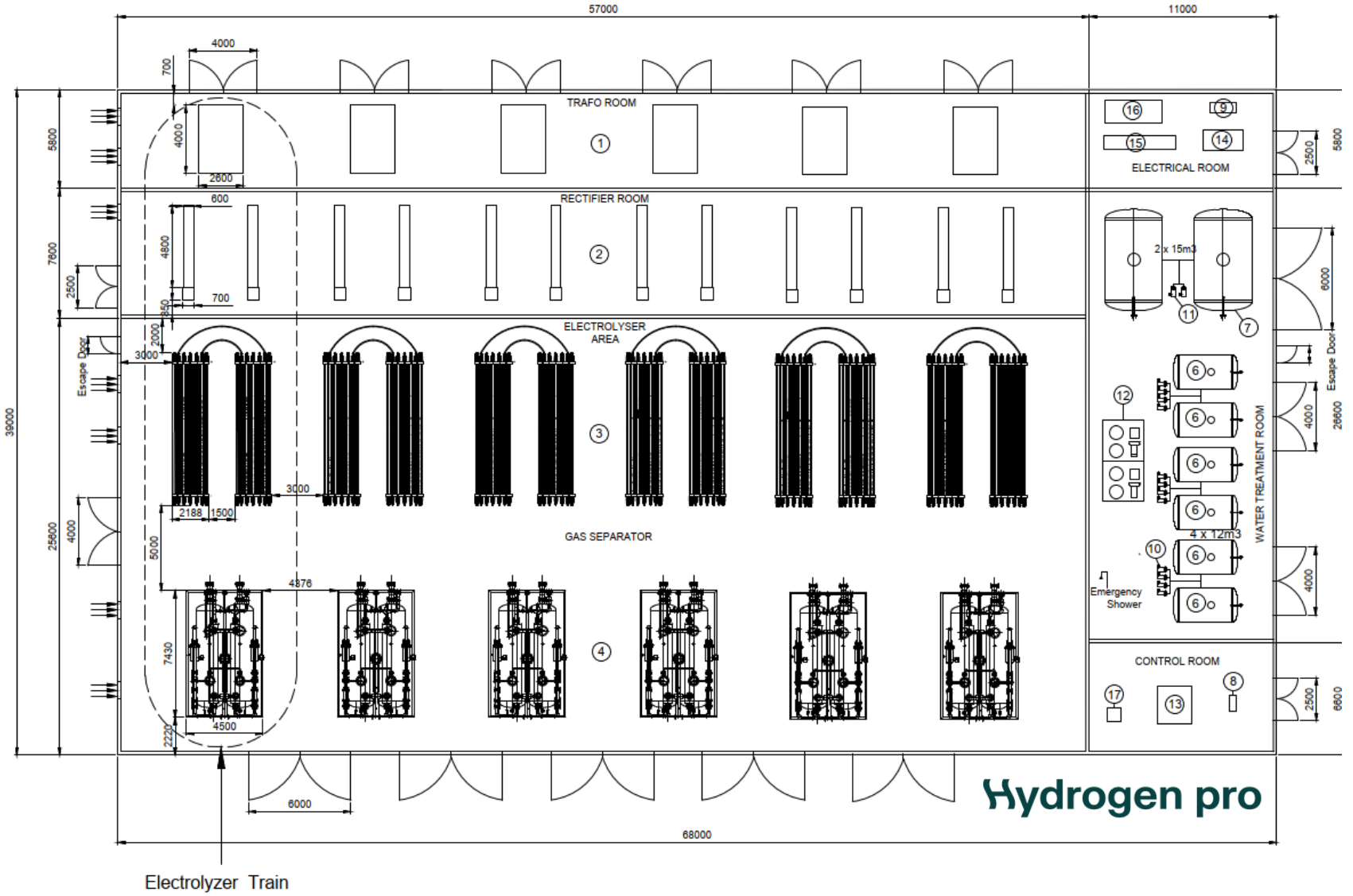
Safety, efficiency and flexibility

1 today‘s stacks
2 today‘s stacks, higher A/m²
3 today‘s stacks, higher A/m², & new electrodes

kWh/Nm³(AC)



A/m²

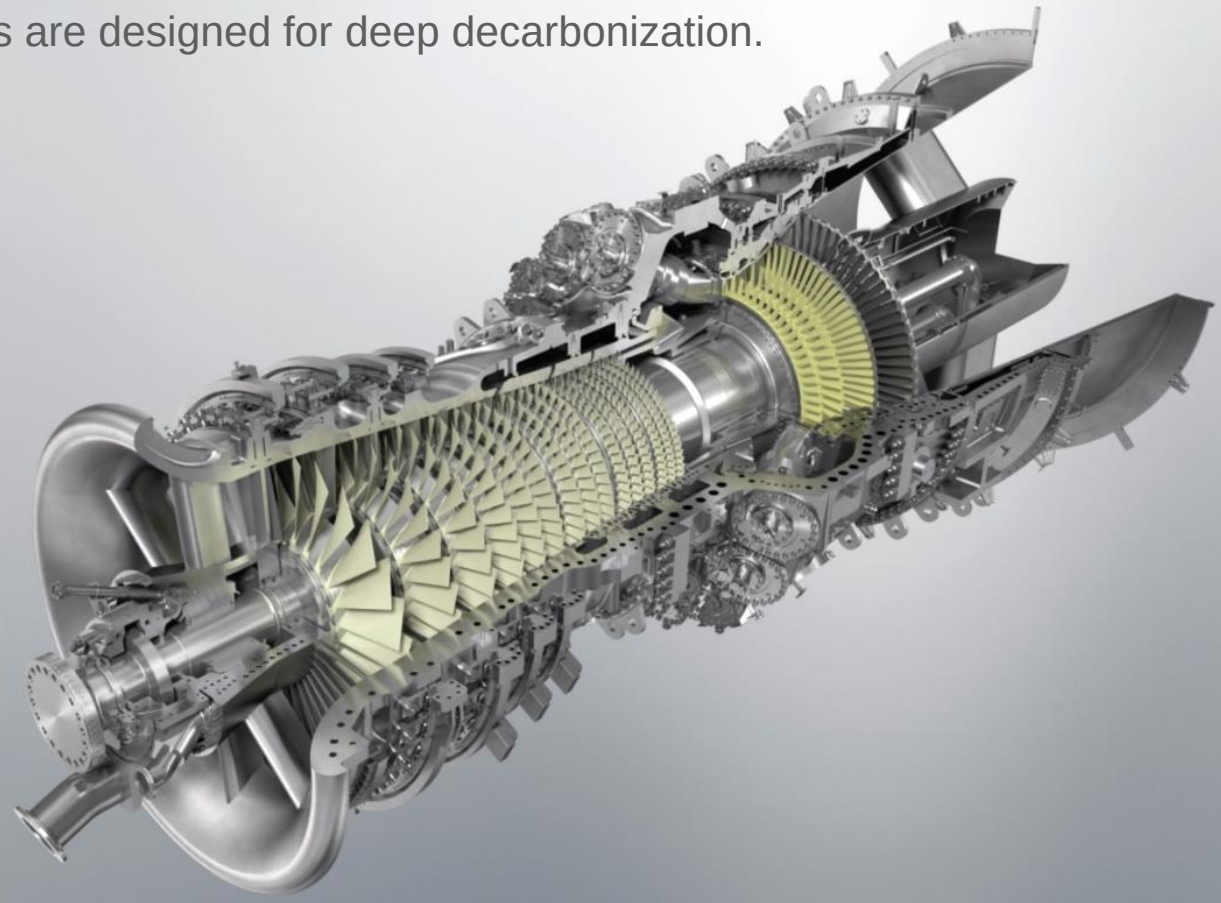


Less than 51 kWh in total to produce 1 kg H2 (already pressurized to 15 bars) (operation mode 3)

Hydrogen fired Gas Turbine

Gas Turbine technology of Mitsubishi Power

Our Advanced Class Gas Turbines are designed for deep decarbonization.



	GT / CC
M701JAC (50Hz)	563MW / 818MW
M501JAC (60Hz)	425MW / 614MW

High Efficiency

Achieved **64%** CC efficiency with
- High pressure compressor (25:1)
- Enhanced air-cooled combustor
- Advanced TBC / Aerodynamics

High Reliability

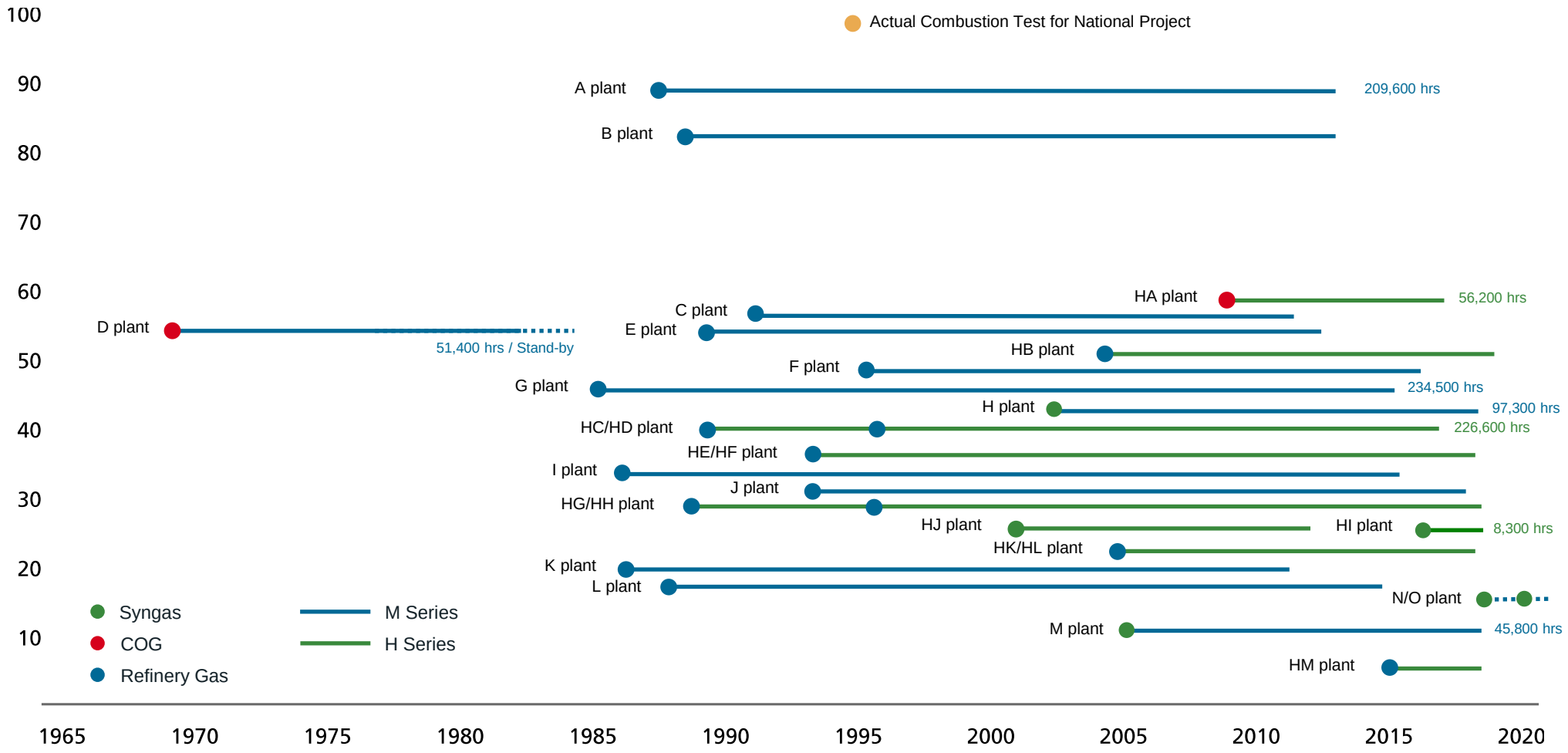
Achieved **99.5%** reliability by
- 60 GT units
- Over 840k operation hours
  (accumulated hours of all J-class units)

Fuel Flexibility

Gas Turbine can be fueled by
- Fossil fuel (Natural Gas, Oil)
- Clean fuel (**Hydrogen**)

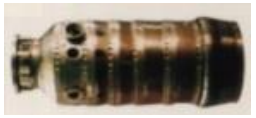
Hydrogen use in Gas Turbines

Mitsubishi Power has successfully demonstrated more than 3.5 million hours of H_2 co-firing across 29 units since the 1970s.



Hydrogen use in Gas Turbines

Currently, Mitsubishi Power has 3 types of combustors catering to individual project requirements and hydrogen densities.

Type	Low NO_x tech	Turbine inlet temperature (˚C)	H_2 density (volume %)	Schedule
Type 1: Diffusion 	N_2 dilution, Water / Steam injection	1200 ~ 1400	**100%**	1970 Cogen/IGCC → **2025 Magnum H_2 conversion**
Type 2: Pre-Mix (DLN) 	Dry	1600	**30%**	1982 DLN → **2018 30% co-firing test completed** (NEDO)
Type 3: Multi-Cluster (DLN) 	Dry	1650	**100% (target)**	**Mar, 2025 Rig test completion target** (NEDO)

Ready

Under development

*This presentation is based on results obtained from a project commissioned by NEDO that is a government organization in Japan.
(NEDO: New Energy and Industrial Technology Development Organization)
**DLN : Dry Low NOx

Solid Oxide Fuel Cell

• Mitsubishi Power SOFC System Product Line Up

220kW Class (Commercialized)
For Commercial & Industry User
(Building, Hospital, Hotel…)

1MW Class (market launch in 2021)
For Utility, Large Industrial Plant &
Micro-grid

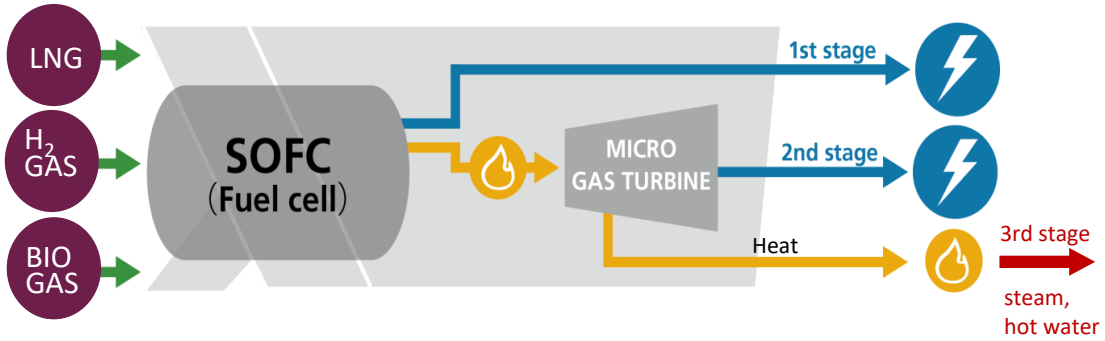
Multi-stage power & heat generation

- Mitsubishi Power-SOFC converts various types of fuel to electricity directly while micro gas turbine utilizes excess fuel from SOFC to generate power.

Electrical Efficiency 55%

Electrical&Thermal Efficiency 73%

(hot water)

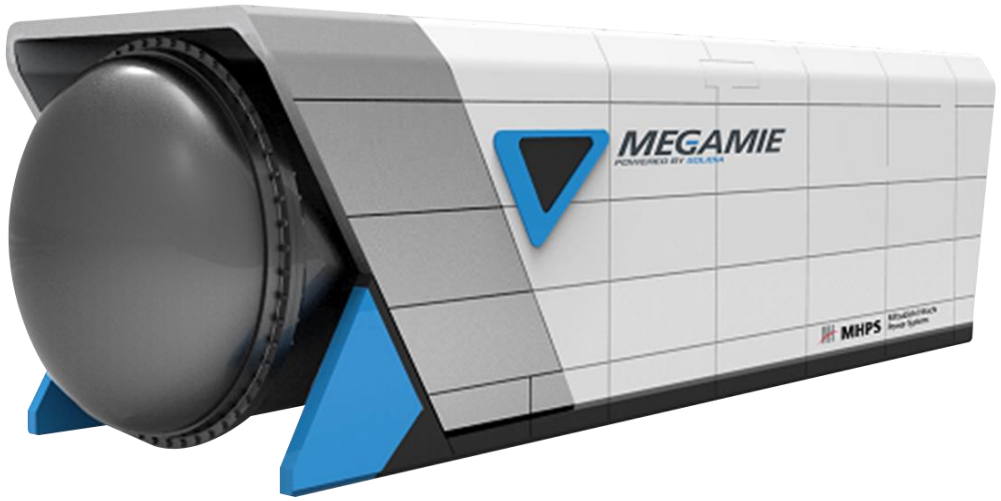


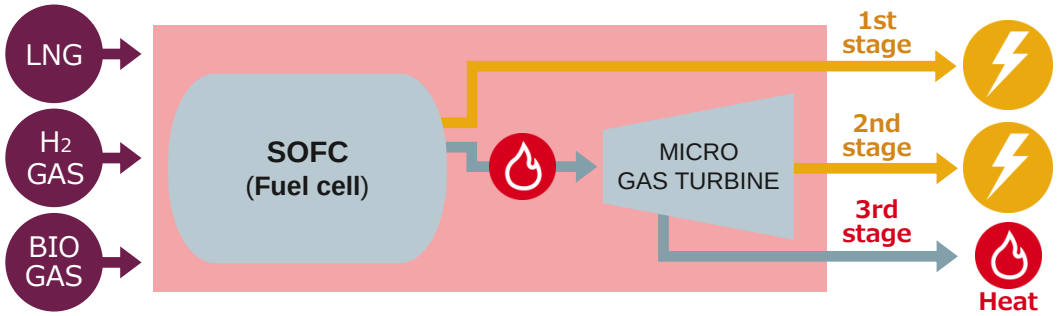
- Due to multi-stage power generation, our SOFC system has proved to have the highest efficiency in all other Distributed Energy Resources at same capacity range

Efficiency Comparison Chart

	PEFC Polymer Electrolyte Fuel Cell	PAFC Phosphoric Acid Fuel Cell	MCFC Molten Carbonate Fuel Cell	Mitsubishi Power-SOFC Solid Oxide Fuel Cell
Temperature (℃)	60～100	150～200	600～650	750～1000
Fuel	Hydrogen	Hydrogen	Natural Gas	Flexible
Efficiency (%LHV)	35～40	38～42	～45	～55

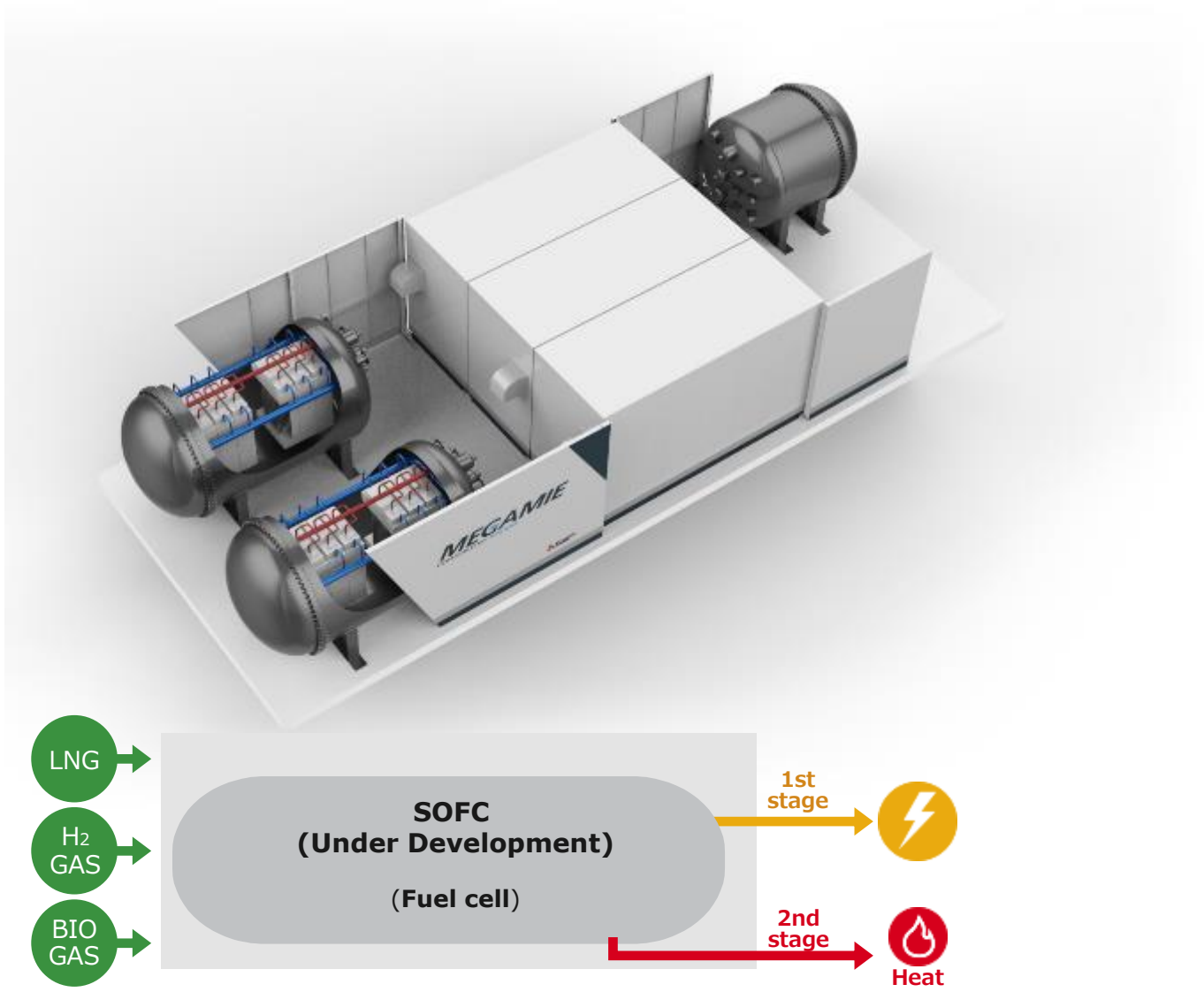
220kW Class SOFC Specification (Commercialized)





Expected Specification	Mitsubishi Power 250kW Class
Electrical Output	220kW class
Electrical Efficiency (LHV)	55 %
Hot water/ Steam Output	86kW/50kW
Total Efficiency (LHV) Electrical + Thermal	73%/65%
Unit Size	W 3.2m x L 12.4 m x H3.3 m
Weight	37ton
Noise Level (Estimated value)	≦65dBA (at 10m far distance)
NOx (16% O_2)	Low Concentration (Depends on the fuel)
SO_x emission	Low Concentration (Depends on the fuel)

1MW-Class SOFC specification *(Under Development)*



Expected Specification	1MW Class
Electrical Output	1,200kW
Electrical Efficiency (LHV)	Approx. 55%
Hot water/ Steam Output	Detail to be discussed
Total Efficiency (LHV) Electrical + Thermal	Later
Unit Size	W: 8.0 m L: 25 m H: 4.0 m
Weight	Approx. 160 ton
Noise Level (Estimated value)	≦65dBA (at 10m far distance)
NOx (16% O_2)	Low Concentration (Depends on the fuel)

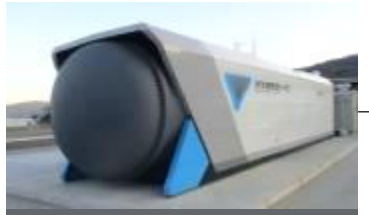
Mitsubishi Power SOFC Supply Record

Overseas: 1 Unit

Commercial Operation @2022

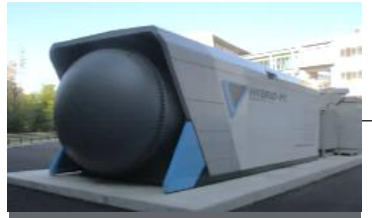
Germany / GWI

Co-generation/ Hot water



J Power

Mono-generation



Kyushu Univ.

Mono-generation

1MW demonstration

Mono generation

Japan: 10 Units

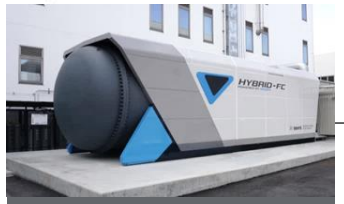
1MW class

210kW class with H2 Rich Fuel

with Biogas Fuel

ASAHI BREWERIES

Co-generation/Steam



TAISEI Corp.

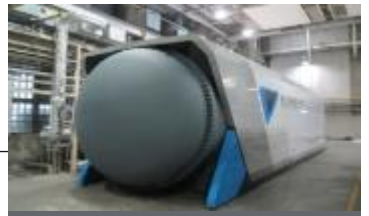
Co-generation/ Hot water

NGK Spark Plug

Co-generation/Steam

Toyota Motor

Co-generation/Steam



Tokyo gas

Co-generation /Hot water

HAZAMA ANDO Corp.

Co-generation /Hot water

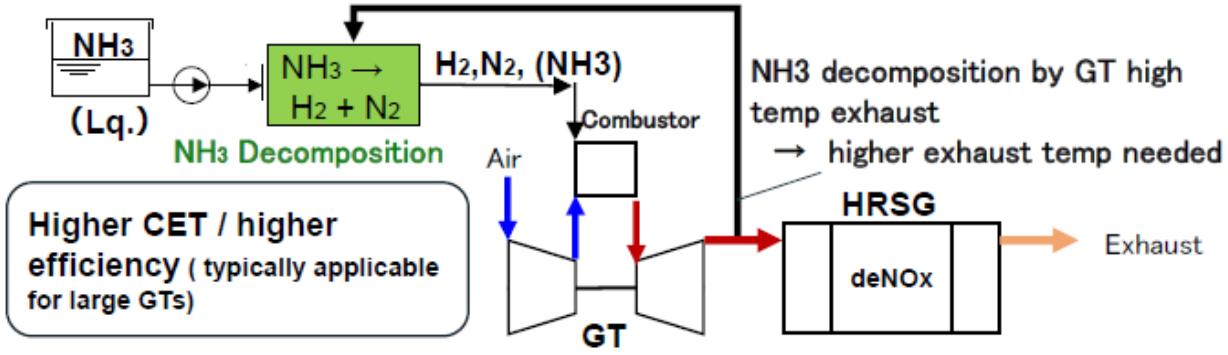
MITSUBISHI ESTATE

Co-generation/Steam

Ammonia use in Gas Turbines and boilers

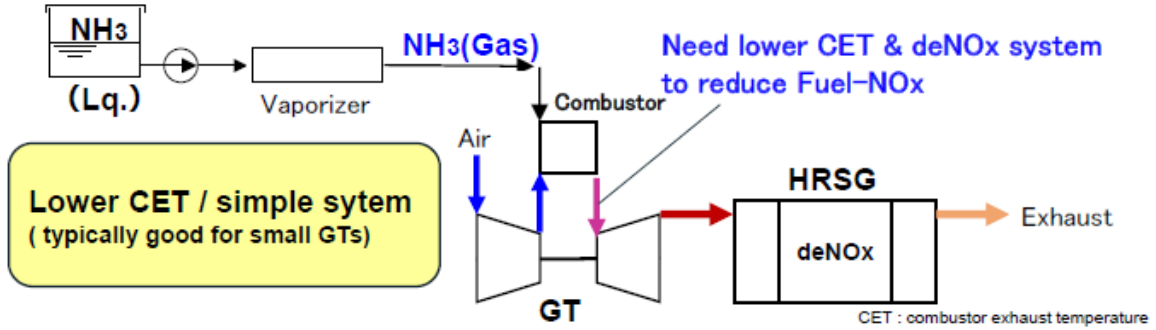
Development program for ammonia utilisation in GTs

■ Ammonia cracking system



H-25 Series gas turbine

■ Ammonia Direct combustion system



PRESS RELEASE

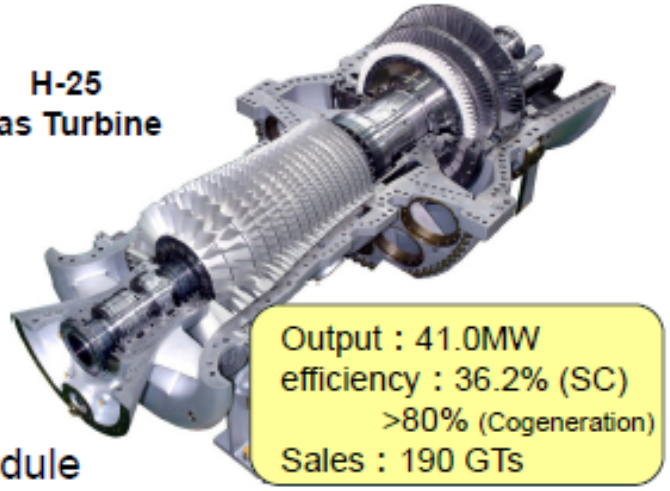
Mitsubishi Power Commences Development of World's First Ammonia-fired 40MW Class Gas Turbine System
-- Targets to Expand Lineup of Carbon-free Power Generation Options, with Commercialization around 2025 --

2021-03-01

Ammonia firing in GT – development programm for H25 (40 MWe class GT)

Mitsubishi Power is now expanding the line-up of carbon free combustion system, not only hydrogen combustion but also ammonia direct combustion.

- ☞ start development of ammonia direct combustor
- ☞ plan to verify the system in 2024
- ☞ start commercial operation from 2025

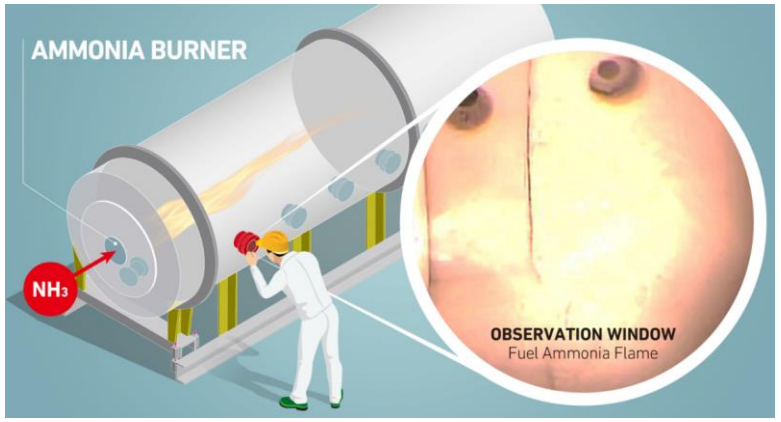


Development Schedule

yr	2021	2022	2023	2024	2025
Combustor Development					
System Design					
Verification					
Commercial operation					

Development program on ammonia firing in boilers

- Development program for 100% ammonia firing in retrofitted industrial boilers ongoing. Pilot tests carried out
- Ammonia co-firing already feasible in existing boilers after retrofit



PRESS RELEASE

Mitsubishi Power to Develop Ammonia Combustion Systems for Thermal Power Plant Boilers
-- To achieve optimal combustion characteristics for mixed and single fuel operations --

2021-08-26

Benefits of Ammonia co-firing/ 100% firing

- Reduced / zero CO_2 emissions
- Higher operating flexibility (better load change rate)

Integrated Projects (Examples)

Mitsubishi Power, Ltd.

Hydrogen for multi-sectoral approach, storage, grid services

electricity

Grid service

Hydrogen compression & storage

H_2

ENERGY Cloud (intelligent control)

Electrolyser

(20-100%)

O_2

electricity

waste heat

Heat pump

CO_2

Power to fuel, industrial use, mobility

CHP

(GT, SOFC, gas engines)

waste heat

heat

Heat (grid)

(0-100%)

flue gas heat

Battery Container

(+/-)

Blueprint for future Hydrogen Energy Hubs!?

Heat storage

Electric Heater

(0-100%)

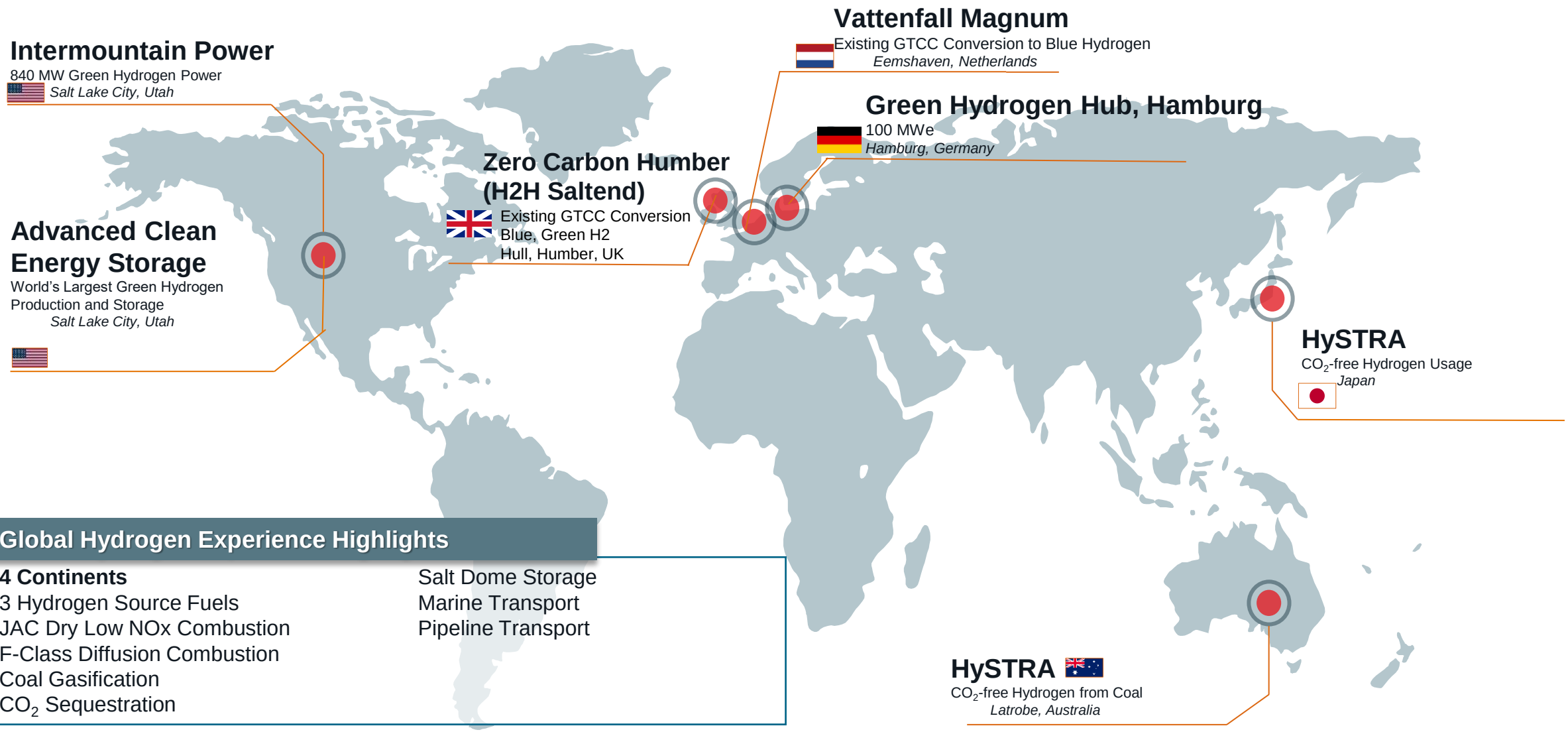
heat

Services & Income streams

- Multiple grid services (flexible operation)
- H_2 sales
- Heat sales
- O_2 sales
- "storage"

>80% total energy efficiency for electrolysis by waste heat utilisation

Mitsubishi Power Hydrogen approach: Learning by doing

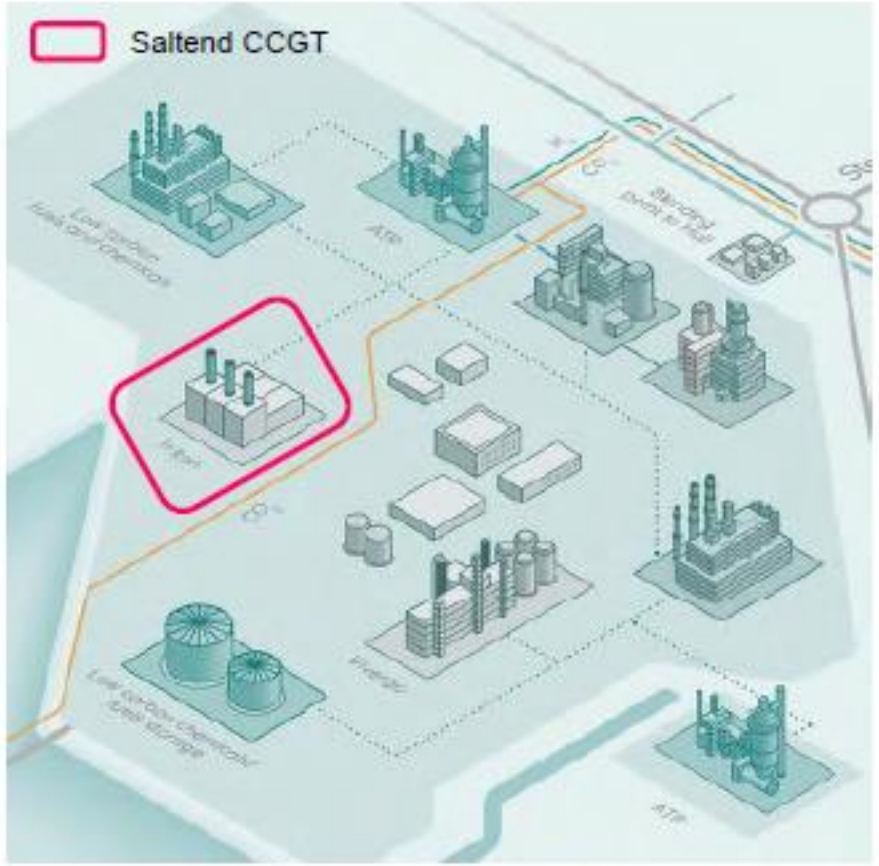


Global Hydrogen Experience Highlights

4 Continents
3 Hydrogen Source Fuels
JAC Dry Low NOx Combustion
F-Class Diffusion Combustion
Coal Gasification
CO_2 Sequestration
Salt Dome Storage
Marine Transport
Pipeline Transport

Zero Carbon Humber (UK)

Feasibility study bid under UK funding.
30% H2 co-firing in Saltend GTCC is the starting point of the project.



Turbine Model	M701F
Power Output	1202 MW (3 GTCC)
Location	Hull, Humber UK

Zero Carbon Humber: a partnership to build the world's first net zero industrial cluster and decarbonise the North of England

30% H2 co-firing in Saltend GTCC by using Blue H2, named H2H Saltend is the starting point of the project.

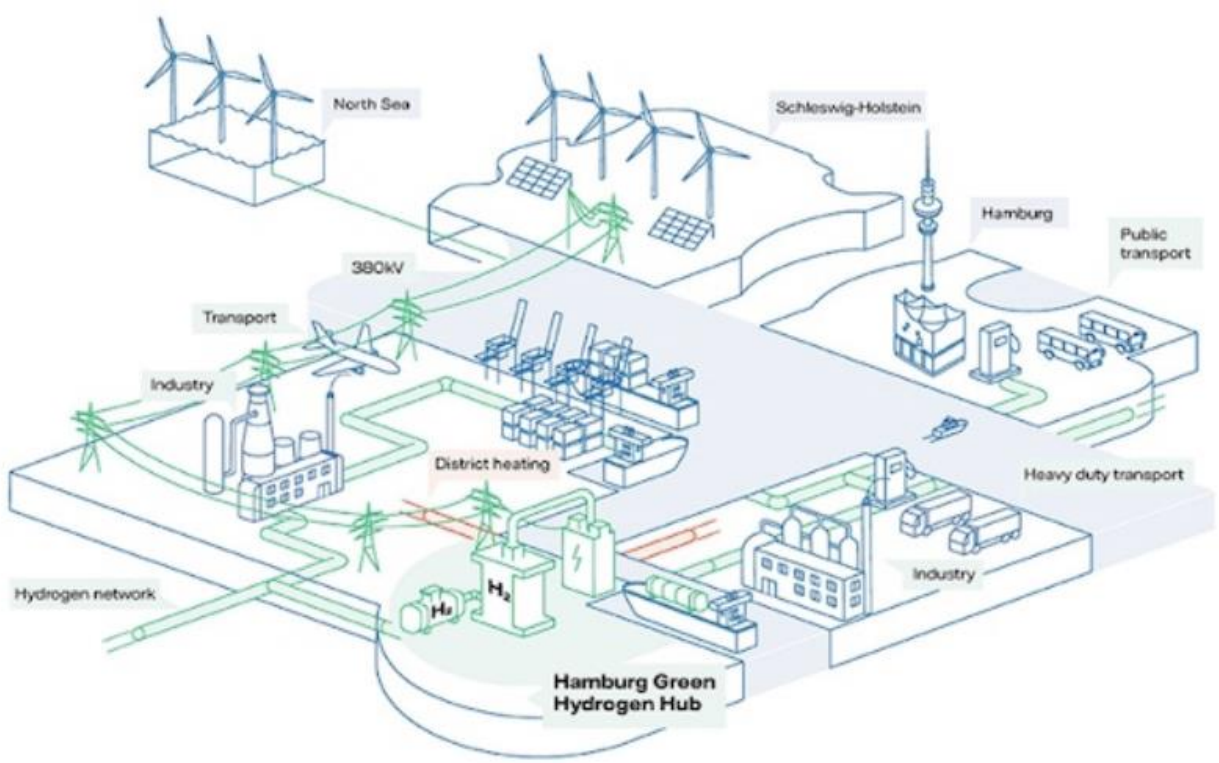
Source and courtesy Equinor

Hamburg Green Hydrogen Hub

Shell, Mitsubishi and Vattenfall partner on Hamburg hydrogen project

Pamela Largue - 1.26.2021

Shell, Mitsubishi Heavy Industries (MHI), Vattenfall and municipal company Wärme Hamburg are exploring a plan to jointly produce hydrogen from wind and solar power at the Hamburg-Moorburg power plant site and utilise it in its vicinity.



Targets

- 100MW(el) electrolyser as first stage, 11500Nm³/h H2 transport & storage via pipeline to users (85bar)
- Supply to industrial customers, transport
- Later extension to X*100MW
- Site: Moorburg PP, Hamburg

Advanced Clean Energy Storage Project

(United States of America)

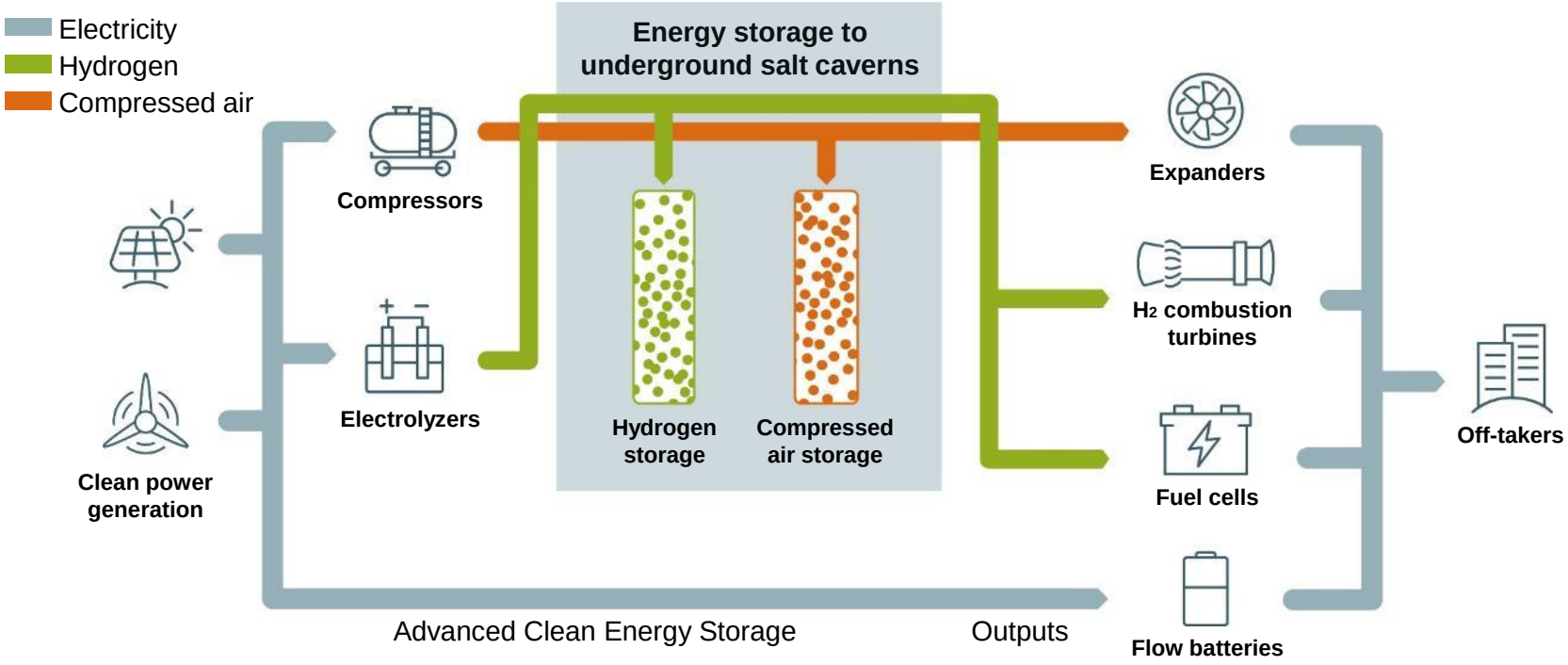
The Advanced Clean Energy Storage Project is the world's largest renewable energy storage project.

Storage Capacity	150GWh
Location	Utah, USA

This project was launched in May 2019 by Mitsubishi Power, Magnum Development and the Governor of Utah.

This project using storage technology such as renewable hydrogen (**Green H_2**), compressed air, large scale flow batteries and solid oxide fuel cells.

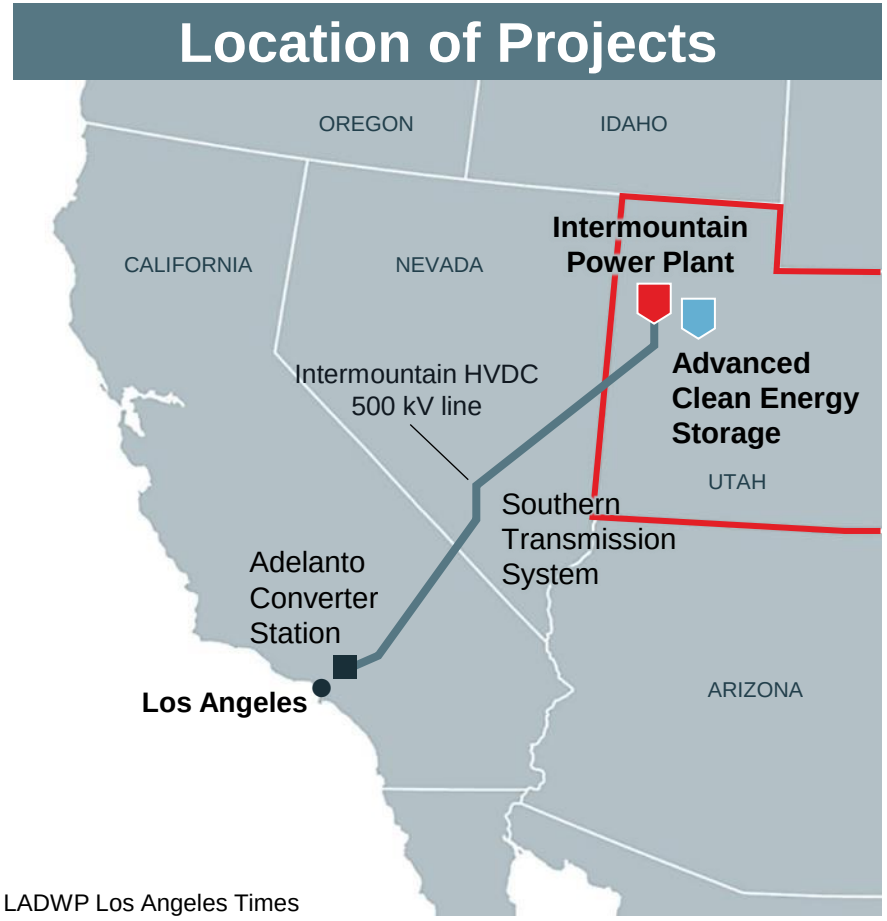
Green H_2 and/or compressed air is planned to be stored in underground salt caverns in Utah.



Intermountain Power Plant (United States of America)

Intermountain Power Agency orders Mitsubishi Power JAC Gas Turbine Technology for Renewable-Hydrogen Energy Hub.

This utility-scale project shows a path to 100% renewable power no later than 2045.



Source: LADWP Los Angeles Times

Gas Turbine Model	M501JAC
Power Output	840 MW (by 2 CCGT)
Location	Utah, USA

This transition will start in 2025 using a mix of 30% hydrogen and 70% natural gas fuel.

This fuel mixture will reduce CO_2 emissions by more than 75% compared to the retiring coal-fired technology.

Between 2025 and 2045, the hydrogen capability will be systematically increased to 100% renewable hydrogen, enabling carbon-free utility-scale power generation.

Power plant is connected to the Los Angeles power grid by an existing high voltage direct-current (HVDC) transmission line.

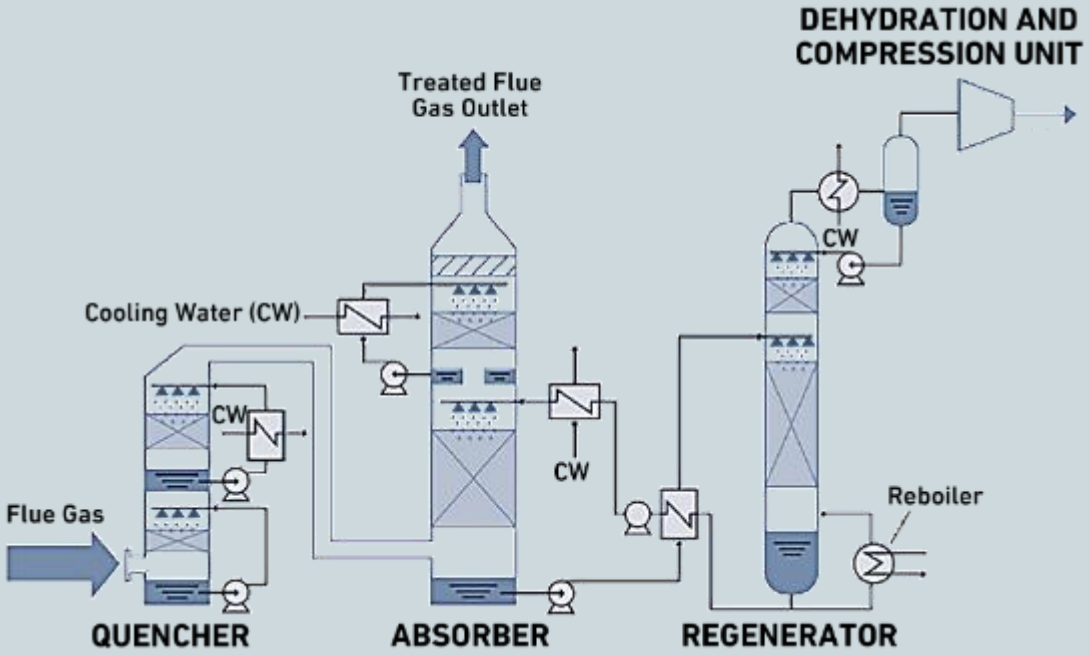
Carbon Capture, CCU

CO2 capture technology of MHI

The world's most energy efficient post combustion process was commercialized 1999 for various flue gas sources (natural gas, heavy oil, biomass, coal) to a variety of usages such as Urea, Methanol or other CO_2 use cases.

- Carbon Capture from Flue Gases with 3% of CO_2 or more
- Purity of CO_2 > 99.9%
- Carbon capture rate over 90%, up to 99.5% possible
- Solvent KS-1™ is negligible corrosive with low consumption
- Over a dozen commercial references

MHI KM CDR™ Carbon Capture Process for Carbon Capture from Flue Gases



- Proprietary hindered amine solvent KS-1™ with low energy, low solvent degradation
- High energy efficiency system
- Amine emission reduction system
- Automatic Load Adjustment (ALAC) System

CO_2 scrubbing - sound reference - key equipment also for PtX (e-fuels)

World‘s leading large scale post – combustion CO_2 capture technology licensor

13 plants in operation and 1 under construction, from a variety of natural gas, heavy oil and coal flue gas sources


1999
210 t/d Malaysia


2005
330 t/d Japan


2006
450 t/d India


2006
450 t/d India


2009
450 t/d India


2009
450 t/d Bahrain


2010
400 t/d UAE


2010
240 t/d Vietnam


2011
340 t/d Pakistan


2012
450 t/d India


2014
500 t/d Qatar


2016
4,776 t/d U.S.A.
largest
ever built


2017
283 t/d Japan

2021
1200 t/d Russia

European Market started

Mitsubishi Power Europe GmbH,
well prepared as licensee of
MHI-ENG Technology
for present tenders

CO_2 Capture and Utilisation (CCU)

MITSUBISHI HEAVY INDUSTRIES

CO_2 - Scrubber Reference

Petra Nova: Texas – USA
World biggest CO_2-scrubber

Start-up: end 2016
4.776 t/day CO_2 production
(flue gas stream of 240 MW hard coal)
90% capture rate

Utilisation:
Enhanced Oil Recovery (EOR)

Flue gas slip stream scrubbing of Boiler #8
(654 MW) W.A. Parish Power Plant / USA

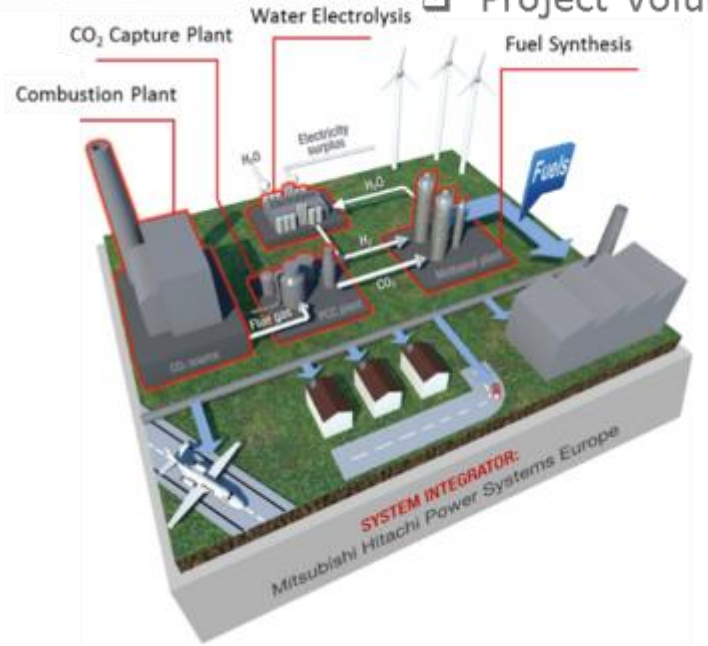
MHI is No. 1 in the world
with over 15 years of experiences
having more than 10 reference plants
for CO_2 scrubbing (PCC technology) in operation

Multi-sectoral Approach: H_2 Conversion to MeOH and DME

Strong engagement by Mitsubishi Power Europe GmbH*
in EU funded multi-party demonstration plants, projects successful and almost completed

MefCO2 : EU SPIRE2 – Horizon 2020
Grand Agreement no.: 637016

- 9 Project partners
- MHPS-EDE as system integrator
- Production of 1 t of Methanol per day
- Project Volume: 11 Mil. EUR



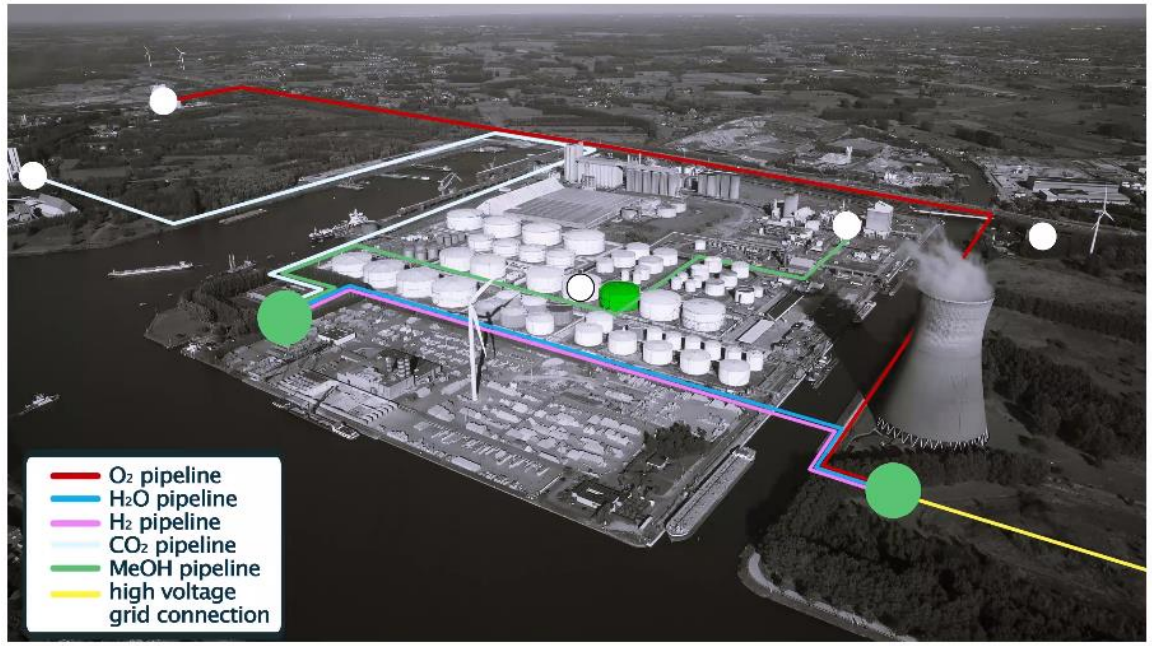
Horizon 2020
European Union Funding
for Research & Innovation

ALIGN-CCUS: EU SPIRE2 – Horizon 2020
Grand Agreement no.: 691712

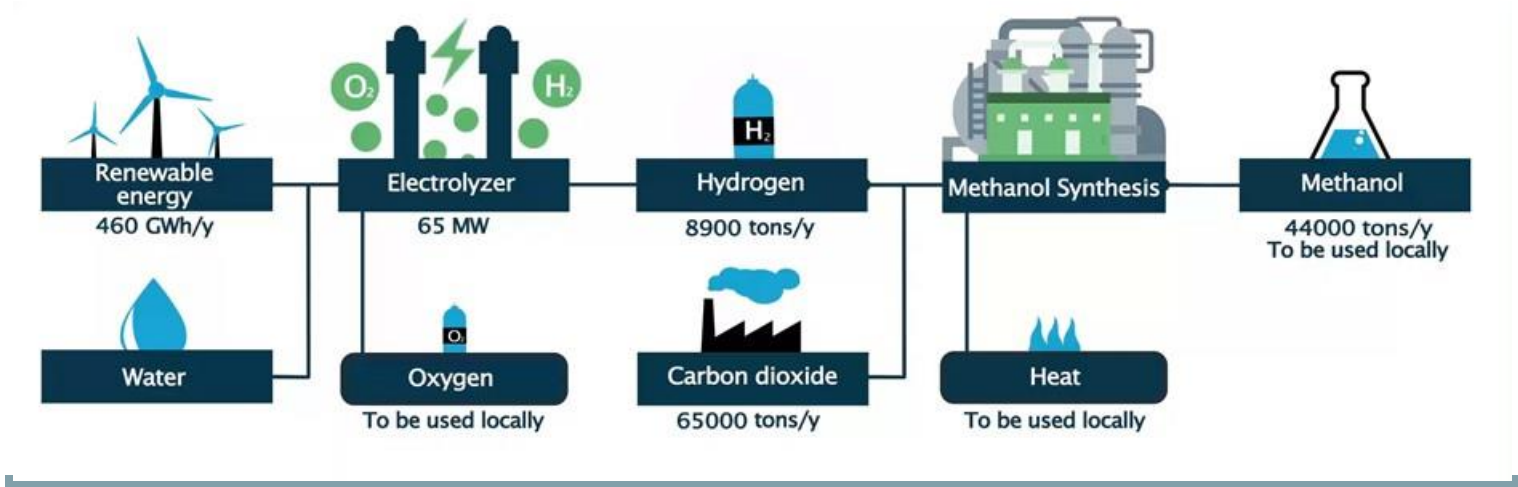
- 31 partners from 5 EU countries working on 6 topics
- WP CO_2 utilization: RWE, AsahiKasei, FEV, FZ Jülich, MHPS-EDE, RWTH; associated partner: BOSCH
- Production of 48 kg of DME mixture per day
- Project Volume: 23 Mil. EUR
- Construction to be completed

*former MHPS-EDE

65MW(el) Synthetic methanol



https://northccuhub.eu/north-c-methanol/

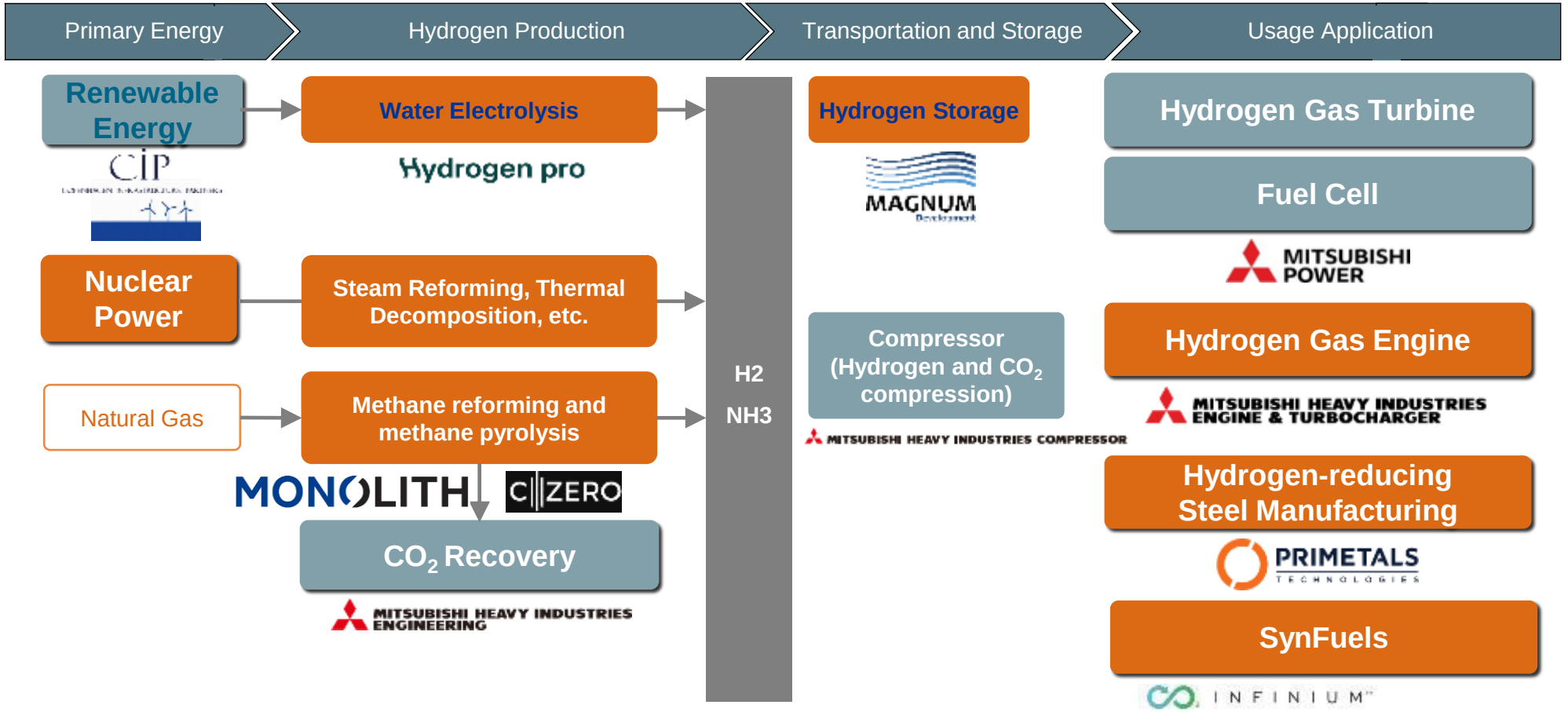


Harbour of Gent/BE
Electrolyser in Rodenhuize PP
Synthesis in harbour area
CO_2 source options
- From nearby ammonia plant
- From bioethanol
- From AM steel mill

Summary

MHI Group Hydrogen Portfolio Capabilities across the Hydrogen Value Chain

- Contributing to the establishment of infrastructure and cost reduction through the provision of technologies, products, and services
- Creating a value chain from hydrogen production to utilization by our unique technologies and active cooperation with partners
- Transition towards utilization of ammonia



White Text: MHI technology **Blue Text: Partnering**
CIP: Development of Offshore Wind Turbines in Hokkaido
Hydrogen Pro: Investing in Hydrogen Production Plant Supply
Magnum : Green Hydrogen Production, Storage and Supply Business Development in Utah, USA

MOVE THE WORLD FORWARD

MITSUBISHI
HEAVY
INDUSTRIES
GROUP